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Kennedy/Jenks Consultants

SITE INVESTIGATION WORKPLAN
DOUGLAS AIRCRAFT COMPANY
TORRANCE (C6) FACILITY
19503 SOUTH NORMANDIE AVENUE
LOS ANGELES, CALIFORNIA
June 1992

Prepared by:

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K/J 924010.00

REVIEWED JH

Kennedy/Jenks Consultants

Engineers and Scientists

[illegible]

29 June 1992

McDonnell Douglas Corporation
Mail Stop 206-1
10775 Business Center Drive
Cypress, CA 90630

Attention: Mr. David Cohen
Senior Corporate Attorney

Subject: Site Investigation Workplan
Douglas Aircraft Company, C6 Facility
19503 South Normandie Avenue
Torrance, CA
K/J 924010.00

Dear Mr. Cohen:

Please find enclosed the Site Investigation Workplan for the subject property, prepared in response to a request from the California Regional Water Quality Control Board - Los Angeles Region, dated 7 April 1992..

If you have any questions, please call.

Very truly yours,

KENNEDY/JENKS CONSULTANTS

W.R. Bazlen for

Thomas C. Deane
Project Manager

William R. Bazlen

William R. Bazlen
Manager, Irvine Office

TDC:WRB/ca
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cc: Boramy Ith

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INTRODUCTION

This workplan has been prepared by Kennedy/Jenks Consultants (K/J), on behalf of the Douglas Aircraft Company (DAC), in response to a request from the California Regional Water Quality Control Board -Los Angeles Region (RWQCB) dated 7 April 1992. The subject site is located at 19503 Normandie Avenue, Los Angeles, California (Figure 1). The area of interest is a former underground storage tank cluster (Tanks 15T through 18T) near Building 36 (Figure 2). The RWQCB has requested a workplan for:

- Definition of the extent of chemically impacted groundwater in the lower flow zone in the vicinity of former underground tank cluster 15T through 18T

- Definition of the extent of chemically impacted groundwater in the hydraulic downgradient direction in the upper flow zone in the vicinity of former underground tank cluster 15T through 18T

- Quarterly groundwater monitoring and reporting for all groundwater wells on the site including; 1) chemical concentration levels in groundwater for aromatic and halogenated volatile organic compounds (VOCs), 2) contoured groundwater potentiometric surface elevations depicting the direction of groundwater flow

The objective of this workplan is provide a basis to meet the RWQCB requests in a prudent and effective manner.

BACKGROUND

Woodward Clyde Consultants (WCC) have performed several subsurface investigations (Phase I, II, and III) in the vicinity of Tank Cluster 15T through 18T. As a result of these investigations, Tank Cluster 15T through 18T appears to be a potential source of detected VOCs in groundwater. WCC has submitted three subsurface investigation reports to the RWQCB dated April 1987, May 1988, and March 1990.

Hydrogeology

The following discussion is based primarily on the WCC Phase III Groundwater and Soil Investigation Report for the site, dated March 1990.

There are two water bearing zones of primary interest beneath the site. The first encountered groundwater zone is approximately 70 to 90 feet below the ground surface (bgs) and is referred to herein as the shallow zone. There are numerous existing groundwater observation wells completed in this zone. Existing shallow zone observation wells are screened from approximately 60 to 90 feet bgs. The shallow water bearing zone is apparently at atmospheric pressure and represents the water table. The March 1990 WCC report indicates a south-southeast groundwater gradient for the shallow zone with a magnitude of 0.002 ft/ft and a groundwater velocity of 0.64 feet/day (234 feet per year). Figure 3 is a reprint of the potentiometric surface contours presented in the March 1990 report. A pumping test (Well WCC-4S) was conducted which indicated an estimated hydraulic conductivity of 715 gpd/ft^2 for the shallow zone (average value of several analytical methods for several observation wells).

Based on boring logs, permeable strata comprising the uppermost level of the second groundwater zone (the deeper zone) have apparently been encountered at depths of 112 feet bgs and 119 feet bgs in the borings for wells WCC-1D and WCC-3D respectively (Figure 2). These are the only groundwater observation wells completed in the deeper zone in this vicinity. Both wells are screened from 120 to 140 feet bgs. This zone is separated from the shallow zone by a yellowish brown to bluish gray silty clay ranging six to nine feet in thickness in wells WCC-1D and WCC-3D respectively. Based on water level data provided in the WCC Phase III report this clay apparently acts as a confining layer to the deeper zone. The potentiometric surface of the deeper water bearing zone is at near the same elevation as the shallow water bearing zone. Both deeper observation well boreholes were terminated in a dark yellowish brown and bluish gray silty clay or claystone at approximately 140 feet bgs. There are insufficient data points (two) to determine the direction and magnitude of the groundwater gradient in the vicinity of Tank Cluster 15T through 18T.

Groundwater Chemistry

A mixture of halogenated, non-halogenated, and aromatic volatile organic compounds have been detected in groundwater samples from observation wells near the former tank cluster. Analysis of available data indicates that elevated levels of 1,1 dichloroethylene (DCE) and trichloroethylene (TCE) have been present in all samples containing other chemicals.

Further analysis indicates that TCE is present in shallow zone groundwater near the site northwest boundary (WCC-10S) in the range of 80 parts per billion (ppb), and TCE and DCE are present in shallow zone groundwater at other well locations upgradient and cross gradient to the tank cluster area in the range of tens of ppb (WCC-2S, -11S, -9S, and -5S). Shallow zone groundwater samples closer to the tank cluster area reveal significantly higher concentrations of TCE and DCE (hundreds to thousands ppb). The data strongly suggest that, while apparent releases from the tank cluster area are contributing to the volatile organic chemical concentrations in groundwater, the background levels of TCE and DCE in shallow zone groundwater in the vicinity of the site are in the tens to one hundred ppb range.

DCE, 1,1,1 Tricholorethane (TCA) and/or TCE have been detected in the range of tens of ppb in deeper zone groundwater at the locations of the two deeper zone observation wells near the former tank cluster (WCC-1D and WCC-3D).

APPROACH

Quarterly Groundwater Monitoring

DAC has initiated a quarterly groundwater monitoring program at the site. The first quarterly sampling round (second quarter 1992) of this program was conducted the week of 15 June 1992 and results of laboratory analyses are pending. A report of laboratory results, groundwater levels, and methodology will be presented to the RWQCB by 15 July 1992.

Additional Groundwater Investigation

The following approach to additional groundwater investigation at the site is predicated on the need to: 1) evaluate all available data concerning groundwater quality and flow characteristics, 2) gather additional data in a judicious and cost effective manner.

Collection of additional shallow zone lithologic and groundwater data using cone penetration testing (CPT), and Hydropunch™ groundwater sampling and the installation of three deeper zone observation wells are proposed. The proposed locations shown on Figure 2. Proposed Hydropunch™ locations may vary pending analysis of the most recent potentiometric surface level data. Upon installation of the first deeper zone observation well, deeper zone groundwater elevation measuresments will be made to obtain the direction of groundwater flow in this zone. The remaining deeper zone observation well locations may be altered if the measured groundwater flow direction is significantly different than anticipated.

The CPT can provide useful lithologic data while Hydropunch™ groundwater samples will provide a basis to place observation wells at the fringe, or downgradient, of known areas of elevated chemical concentrations. Hydropunch™ samples will be analyzed for VOCs, at a California certified laboratory, using EPA Method 8240. The potential existence of a cemented fossiliferous sand layer at approximately between 30 and 45 feet bgs may impede further progression of the CPT and Hydropunch™ tools.

Prior to determining exact locations for additional shallow zone groundwater observation wells, it is prudent to await the results of the recent groundwater sampling and water level measurements. In addition, requests have been made to the RWQCB, and other agencies, to review environmental reports for surrounding properties. The earliest review dates granted by the RWQCB are near the end of June 1992. It is important that the locations of, and data from, existing off-site observation wells be reviewed to assess the regional groundwater quality problem and avoid duplication of existing observation well usefulness.

Shallow Zone

The RWQCB letter of 7 April 1992, addressed to DAC, comments that there is a need to define the extent of the "contaminant plume" downgradient of former Tank Cluster 15T through 18T. In addition, the RWQCB comments that water quality data from wells WCC-5S and WCC-9S indicate that the "contaminant plume may have migrated off-site," thereby requiring investigation of off-site groundwater quality data.

The proposed locations of four shallow zone CPT/Hydropunch™ are shown on Figure 2. HP-1S is located upgradient of the tank cluster and has been chosen to attempt to evaluate the upgradient groundwater quality.. The HP-2S and HP-3S locations are intended to attempt to identify the lateral and downgradient extent of elevated chemicals of concern potentially associated with the tank cluster. HP-4S is located along the site eastern boundary. Available water level data suggest that this location is not necessarily downgradient of chemicals attributable to the former Tank Cluster 15T through 18T. This location is included in this program to aid in determination of groundwater chemical conditions at the property boundary. The shallow Hydropunch™ samples will be taken in the bottom one-quarter of the shallow saturated zone (approximately 85 feet bgs).

No off-site groundwater sampling locations or observation well locations are recommended at this time. Results from all available data must be analyzed. Currently available data do not strongly point to chemicals in observation wells WCC-5S and WCC-9S originating onsite. The chemical concentrations and species found in groundwater samples from these wells indicate that impacted groundwater at these locations may be part of a larger regional problem. Data from adjacent properties, current chemical concentration levels, and groundwater potentiometric surface data over time should be analyzed prior to recommending off-site observation wells.

Deeper Zone

Three deeper zone groundwater observation wells are proposed. As discussed above, depth to groundwater in W-4D will be measured and converted to elevation to ascertain an estimated groundwater gradient in the deeper zone prior to installing the W-2D and W-5D. The proposed locations of W-2D and W-5D may be altered if the measured groundwater flow direction is significantly different than assumed.

FIELD METHODOLOGY

CPT and Hydropunch™

The CPT and Hydropunch™ technologies are well documented in the literature. A reprint of an article, explaining the Hydropunch™, published in the Summer 1989 issue of Groundwater Monitoring Review, is attached to this workplan.

The CPT will be conducted with a large (20 ton) rig specifically designed for this purpose. The rig hydraulically pushes 1.5-inch steel rod with either an electronic friction cone-tipped cylindrical probe or Hydropunch™ sampling tool attached to the end. The cone-tipped probe measures friction resistance along the side of the probe and soil resistance on the cone tip. The device is calibrated to allow calculation of inferred soil descriptions (lithology) from the resistance readings.

The resulting borehole will be grouted with neat cement during withdrawal of the rod. The CPT rig is equipped with a self-contained decontamination system that steam cleans the CPT rod while it is being withdrawn from the ground. Rinsate water is contained inside an enclosed chamber and will be pumped to suitable containers (55 gallon DOT approved drums or temporary storage tanks) for subsequent disposal.

Typical Observation Well Construction

Observation well boreholes will be drilled using Dual-Wall Percussion Hammer Techniques. The dual wall technique drives a ten-inch diameter dual wall casing into the ground with a percussion hammer. Soil cuttings are lifted through the annulus of the dual casing walls by compressed air. The driving of the casing effectively seals off the borehole annulus thereby reducing the potential of inter-water bearing zone hydraulic connection. The casing provides a stable borehole for well construction while eliminating the need for drilling fluids other than compressed air and minor amounts of potable water.

The observation wells will be constructed of 4-inch diameter PVC materials. Based on earlier studies at the site, the screened section of each well will consist of 0.010-inch factory slotted well screen and the filter pack will be a Lonestar No. 30 sand (or equivalent). Screened intervals will consist of approximately 20 foot lengths of factory slotted Schedule 40 threaded PVC, equipped with a threaded end cap, and set approximately 120 to 140 feet bgs. Blank casing will consist of Schedule 40 threaded PVC well casing equipped with a PVC slip-on cap. A typical proposed groundwater observation well construction design is shown on Figure 4.

To ensure that the casing string is centered in the borehole to attain a relatively even filter pack, stainless steel casing centralizers will be installed at the top, mid-point and bottom of the screened interval and at a minimum of every 40 feet of blank casing. The well casing string will be suspended in the borehole from ground surface such that it does not rest on the bottom of the borehole. All well casing connections and fittings will be threaded. No glue or thread lubricants other than Teflon[R] will be allowed. Prior to observation well construction, all well construction materials (i.e., well casing, centralizers, etc.) will be steam-cleaned.

The clean, washed Lonestar No. 30 (or equivalent) sand filter pack will be emplaced into the borehole annulus around the well screens utilizing a temporary tremmie pipe. The filter pack shall be tremmied with a 2-inch-diameter pipe through the drive casing from the bottom of the borehole to a depth approximately three feet above the top of the well screen. During installation of the filter pack, the drive casing will be periodically raised such that a portion of the filter pack is maintained within the lower portion of the drive casing to prevent the borehole from collapsing around the well casing. Prior to placing a bentonite seal on top of the filter pack, each well will be surged with a vented surge block to settle the filter pack. In the event that the upper surface of the filter pack drops as a result of this surging, additional sand will be installed. In addition a two-foot layer of "sugar sand" (Lonestar No. 60 or equivalent) shall be added on top of the sand filter pack to approximately five feet above the well screen.

A bentonite seal consisting of pelletized bentonite will be free-fallen through the drive casing into place directly above the filter pack to provide an approximate three- to five-foot-thick seal in the well annulus. Prior to installing the sanitary seal, the bentonite seal will be allowed to hydrate a minimum of 45 minutes.

A cement/bentonite slurry sanitary seal will be installed from the top of the bentonite seal to approximately five feet bgs through the use of a temporary tremmie. The slurry will be prepared by adding three to five pounds (i.e., 3 to 5% by weight) of powdered bentonite to seven to ten gallons of potable water per 94-pound sack of cement. During installation of the sanitary seal, the bottom of the tremmie will be kept submerged in the grout to maintain a continuous seal, and the drive casing will be periodically raised to maintain a continuous seal and a stable borehole.

The top of the well casing of each observation well will be completed below grade and protected with a locking steel stovepipe and a traffic-rated Christy-type surface box. After the PVC well casing has been cut off approximately one foot below grade and fitted with a slip-on PVC cap, the well casing will be secured with a locking mild-steel casing. This casing will be set into a concrete surface seal such that the top is approximately six inches below ground surface. The watertight Christy-type surface box will be centered in an 8-inch-thick concrete pad such that the upper surface of the cement apron is sloped away from the well to direct surface runoff water away from the well.

After observation well construction, each well will be surveyed to mean sea level for vertical and horizontal control.

Observation Well Development

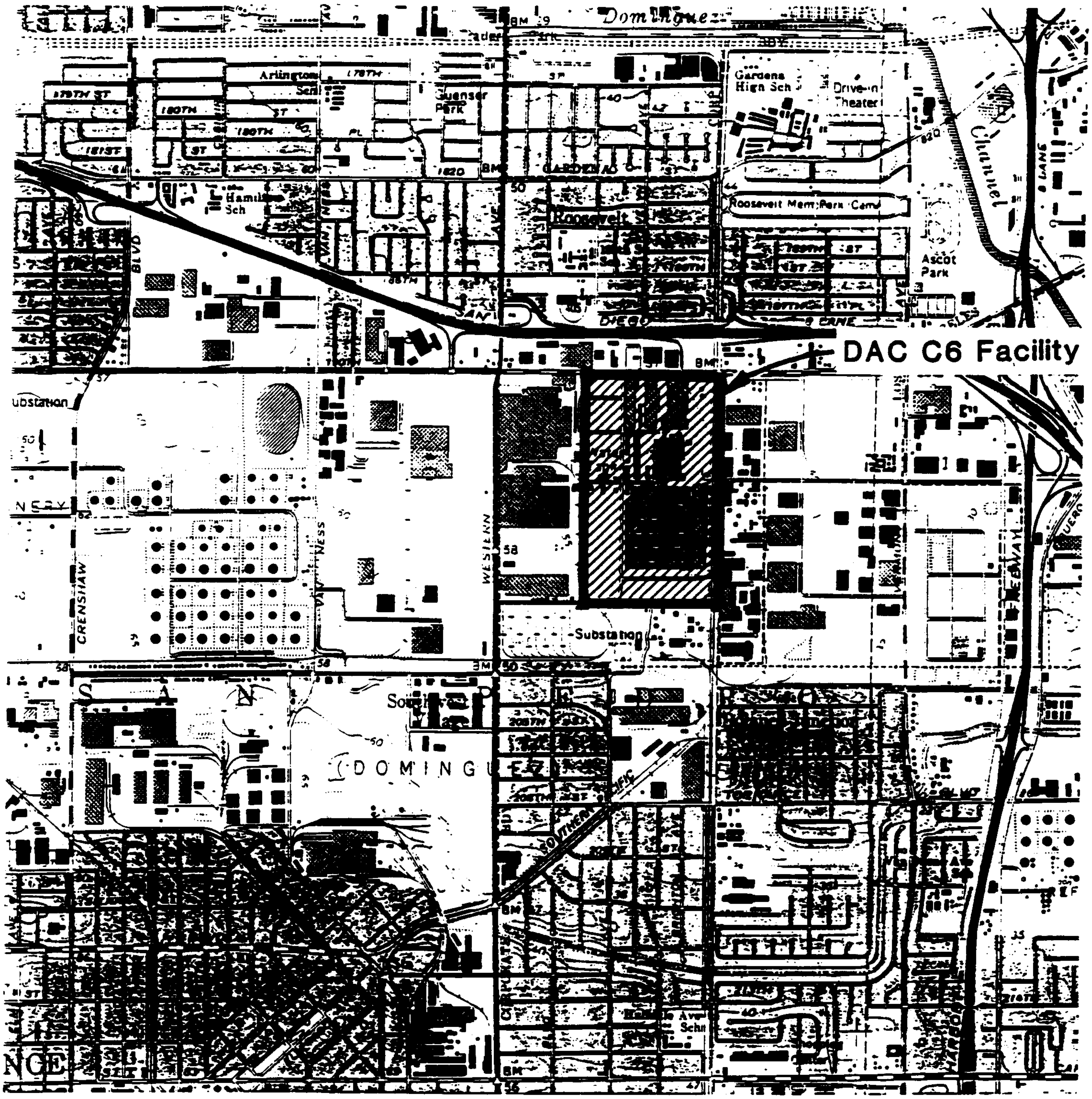
After a minimum of 72 hours have elapsed, each newly constructed observation well installed during this investigation will be developed by utilizing mechanical and pump development techniques. Initially, each well will be mechanically developed by surging and bailing. The wetted portion of the well casing screen will be alternately surged and bailed until essentially no sediments are brought into the well casing. Each well will be surged using a tight-fitting surge block and sediments (if any) brought into the well casing will be removed through the use of a stainless steel suction-type bailer.

After it has been determined that additional sediments cannot be brought into the well casing through mechanical methods, each observation well will be pump developed by temporarily installing an electric submersible pump to the approximate mid-point of the wetted casing and groundwater will be purged until all visibly suspended solids are removed from the well (i.e., purge-water is clear) and the following parameters have stabilized: electrical conductivity, pH, and temperature. During observation well development, a minimum of 10 wetted well casing and borehole volumes will be purged.

Observation Well Groundwater Sampling and Laboratory Analyses

Following well development, groundwater from each new observation well will be sampled. If the construction dates are relatively close to a scheduled quarterly sampling event, new well sampling will coincide with quarterly sampling. Groundwater sampling will follow standard procedures and quality control/quality assurance procedures as documented in the upcoming Second Quarter 1992 Groundwater Monitoring Report.

All groundwater samples will be analyzed for volatile organic compounds, at a California certified laboratory, using EPA Method 8240.



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0 1,000 2,000 FEET

Base Map: U.S.G.S. 7.5 Minute Topographic Map,
Torrance, California Quadrangle, 1981.

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Site Vicinity Map

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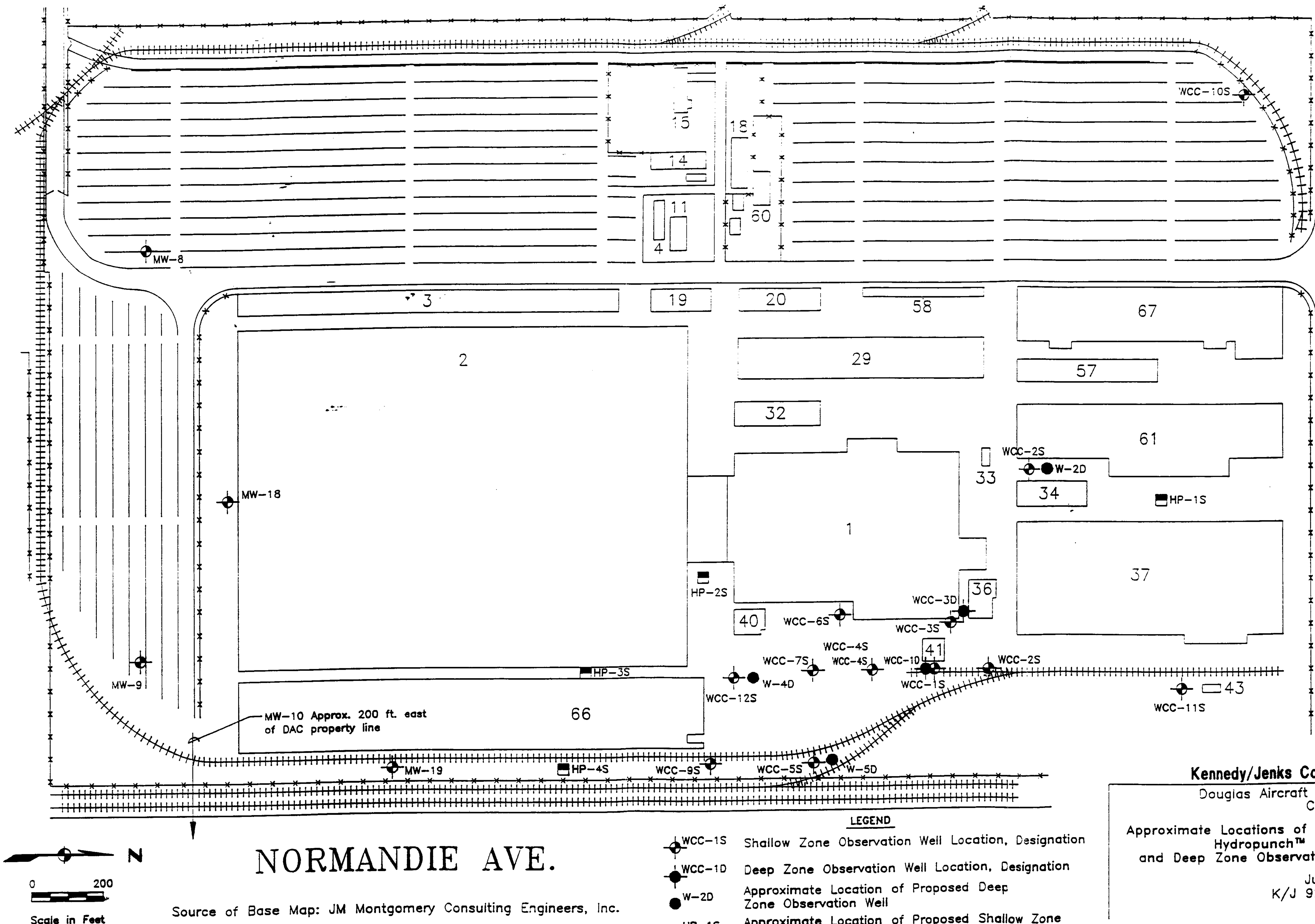
Figure 1



Source of Base Map: JM Montgomery Consulting Engineers, Inc.

LEGEND

WCC-1S	Shallow Zone Observation Well Location, Designation
WCC-1D	Deep Zone Observation Well Location, Designation
W-2D	Approximate Location of Proposed Deep Zone Observation Well
HP-1S	Approximate Location of Proposed Shallow Zone Hydropunch™ Sample

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Approximate Locations of Proposed Hydropunch™ Samples and Deep Zone Observation Wells

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Figure 2

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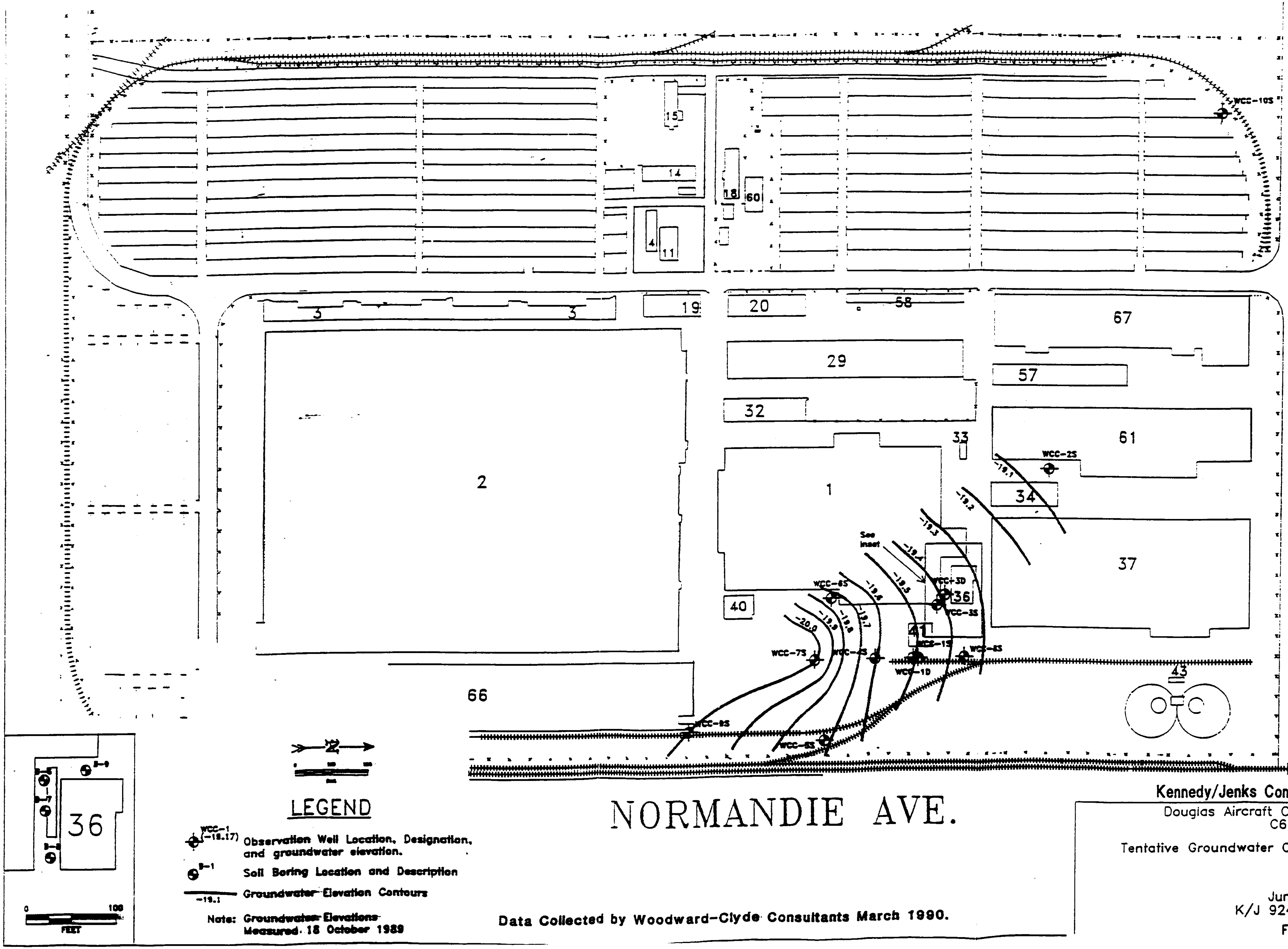

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Tentative Groundwater Contours

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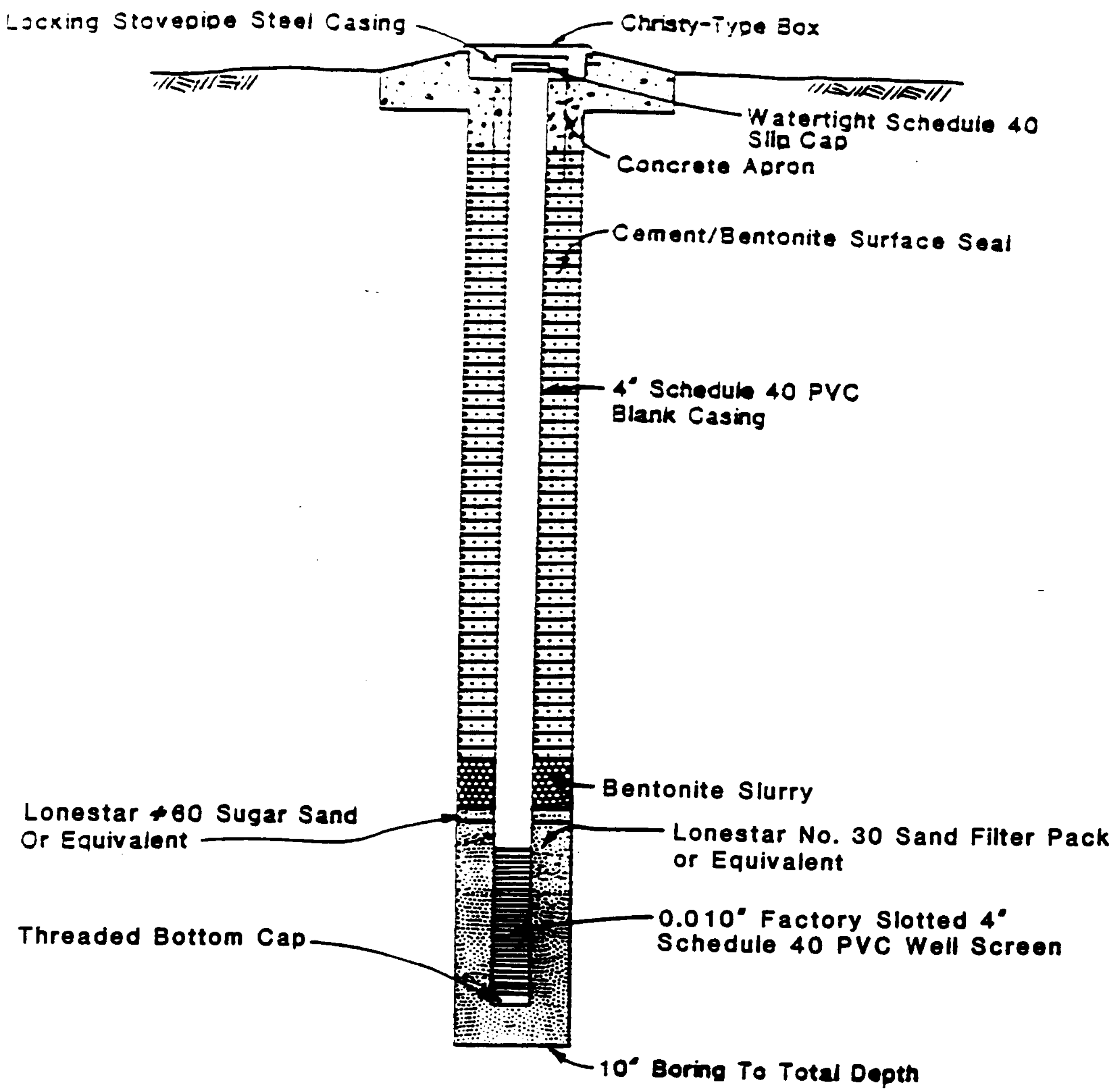
Figure 3



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Site Investigation Work Plan for
Douglas Aircraft Company

Typical Proposed Groundwater Observation Well Design

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Figure 4

ATTACHMENT A

to

SITE INVESTIGATION WORKPLAN
DOUGLAS AIRCRAFT COMPANY
TORRANCE (C6) FACILITY
19503 SOUTH NORMANDIE AVENUE, LOS ANGELES, CALIFORNIA
K/J 924010.00
June 1992

The Hydropunch™: An In Situ Sampling Tool for Collecting Ground Water from Unconsolidated Sediments

by Russel W. Edge and Kent Cordry

Abstract

The Hydropunch™ is a stainless steel and Teflon® sampling tool that is capable of collecting a representative ground water sample without requiring the installation of a ground water monitoring well. To collect a sample, the Hydropunch (Patent #4669554) is connected to a small-diameter drive pipe and either driven or pushed hydraulically to the desired sampling depth. As the tool is advanced, it remains in the closed position, which prevents soil or water from entering the Hydropunch. Once the desired sampling depth is obtained, the tool is opened to the aquifer by pulling up the drive pipe approximately 1.5 feet (0.46m). In the open position, ground water can flow freely into the sample chamber of the tool. When the sample chamber is full, the Hydropunch is pulled to the surface. As the tool is retracted, check valves close and trap the ground water in the sample chamber. At the surface the sample is transferred from the Hydropunch to an appropriate sample container. The tool is a fast, inexpensive alternative for collecting ground water samples from a discrete interval. It is excellent for vertical profiling or defining the areal extent of a contaminant plume.

Introduction

Increased public awareness and concern over toxic chemicals in our ground water resources has resulted in a dramatic increase in the number of ground water investigations being conducted in the United States. The cornerstone of these investigations is the ground water monitoring well. Monitoring wells are used to determine if ground water contamination exists at a selected location, to quantify the concentration of contaminants in the ground water, and to define the vertical and horizontal extent of contamination. During the past decade, improved analytical techniques and a better understanding of ground water monitoring requirements have made the installation, development, and sampling of ground water monitoring wells increasingly more sophisticated. Increased sophistication has resulted in a corresponding increase in the cost and time required to complete the typical ground water monitoring well. It has been estimated that the average cost of drilling and installing a single ground water monitoring well has increased approximately $2000 to more than $6000 in the last years. This figure does not include well development sampling costs. At sites where ground water and soil are classified as hazardous and must be containerized and transported to suitable locations for disposal, costs for well installation, development, and sampling will be substantially higher. These increased costs are due in part to the volume of material to be disposed of, increased health and safety requirements, detailed sampling protocol, and more stringent QA/QC.

In addition to increased cost, the time between the installation of a ground water monitoring well and the time when a ground water sample is actually collected can become quite lengthy. For small investigations (using five or fewer relatively shallow wells drilled with hollow-stem augers, as an example) it is typically a matter of days or weeks between the time drilling is initiated to when ground water samples are collected. It has been the authors' experience on medium- and large-scale investigations (six or more monitoring wells) that weeks or months pass between the initiation of drilling and ground water sampling. This is primarily a result of scheduling the drilling, development, and sampling crews in the most efficient manner. Ideally, all monitoring wells are installed, then developed and finally sampled. For a project involving numerous ground water monitoring wells it requires a considerable period of time to receive meaningful geochemical and hydrogeologic data.

The exploratory nature of hydrogeologic investigations often results in many wells which for one reason or another are only sampled once. Often the wells are found to be misplaced either horizontally or vertically in relationship to the contaminant plume. At sites with a complex hydrogeologic environment, and where little hydrogeologic data are available, sometimes as many as half of the initial monitoring wells installed can be improperly located. Another problem associated with misplaced monitoring wells is that once the well is installed, the temptation exists to continue to sample the well regardless of the usefulness of the data.

Due to the cost and time associated with ground water monitoring wells, many investigators have used secondary detection techniques (i.e., geophysical methods and soil-gas sampling) in an attempt to define the horizontal extent of contaminant plumes. At sites where the hydrogeologic and contaminant conditions are suitable, secondary detection methods have proved to be quite valuable. Unfortunately, at many sites where conditions are less than ideal, the results were found to be confusing. Occasionally, little or no correlation can be made between the concentrations derived from indirect detection methods and contaminant concentrations found in monitoring wells that were subsequently installed.

In December 1984, a conceptual model was developed for a tool that would enable investigators to quickly collect a ground water sample without requiring the installation, development or sampling of a ground water monitoring well. The goal was to devise a fast, inexpensive method to collect a single ground water sample suitable for priority pollutant analysis. If successful, the tool would reduce the number of monitoring wells needed to complete a ground water investigation and would provide more accurate, quantifiable ground water contaminant concentrations than existing secondary detection methods. The first prototype of such a sampler, later called the Hydropunch, was completed in March 1985.

Overview of the Hydropunch Components and Their Functions

The Hydropunch ground water sampling tool was designed to be used in two modes, utilizing either cone penetrometer equipment or conventional drilling equipment, to push or drive the tool to the desired sampling depth. The sampler is constructed entirely of stainless steel and Teflon, is easily cleaned in the field, and will collect approximately 5mL of sample. The Hydropunch has a stainless steel drive point, a perforated section of stainless steel pipe for sample intake, a stainless steel sample chamber, and an adapter to attach the unit to either penetrometer push rods or standard soil sampling rods (Figure 1).

As the unit is pushed or driven through the soil, the sample intake tube is retained in the sample chamber (in a watertight housing), which prevents contaminated soil or ground water from entering the unit. The shape of the sampler and its smooth exterior surface prevents the

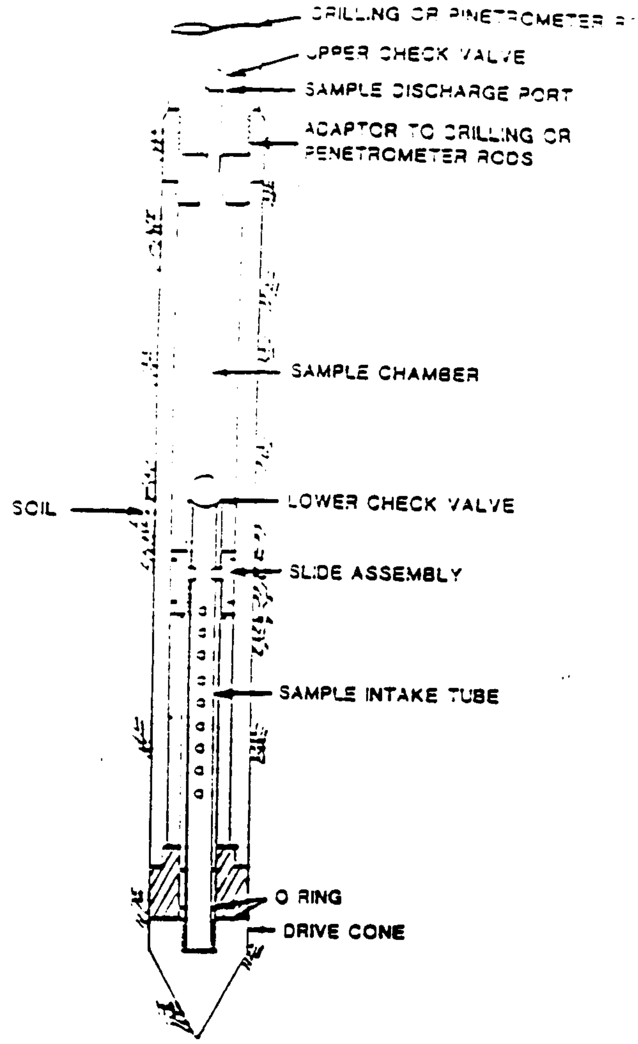
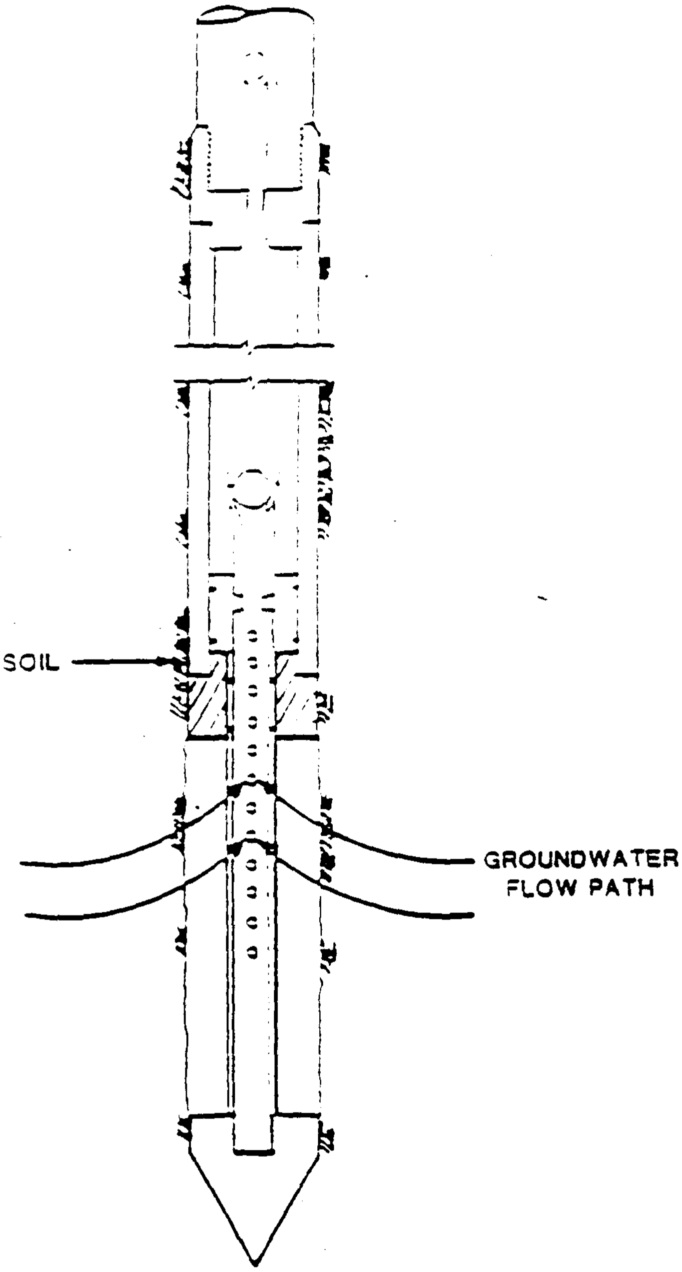


Figure 1. Hydropunch schematic.

downward transport of the surrounding soil and liquid as the tool is advanced. When the desired sampling depth is reached, the sample chamber is withdrawn approximately 1.5 feet (0.46m). The drive cone, which is attached to the intake tube, is held in place by soil friction. As the sample chamber is retracted, the drive cone pulls the perforated intake tube from inside the sample chamber and exposes it to the water-bearing zone (Figure 2). Once exposed, ground water flows through the intake tube and into the sample chamber. Unlike monitoring wells, no foreign materials (i.e., gravel pack, drilling fluid or cuttings) are introduced into the zone being sampled, minimizing the possibility of sample quality being influenced by extraneous contaminants. As the sample is collected, the drive cone and the sample chamber are flush against the borehole walls, sealing the intake tube from ground water above and below the zone being sampled. This permits ground water samples to be collected from a discrete vertical interval. The sample is collected under in situ hydrostatic pressure with no aeration and minimal agitation. Once the sample chamber is filled, the Hydropunch is retrieved. Similar to a bailer, the upward movement of the sampler increases the hydrostatic pressure in the unit, which closes the two check valves and retains the sample within the sample chamber. Upon retrieval, the push rods



gure 2. Once exposed, ground water flows through the intake ube and into the sample chamber.

e disconnected from the Hydropunch and the upper all check valve is removed. The drive cone is removed, d a sample discharge tube is inserted in the lower end of unit. The sample can then be transferred to a sample ntainer through a Teflon stopcock and tubing.

ydropunch Operations

Where the geologic conditions are suitable for cone enetrometer soundings (normally characterized by rela- ely soft, fine- to medium-textured soils), the Hydro- nch can be rapidly pushed to the desired sampling pth by a cone penetrometer rig. Since the late 1930s, eotechnical investigations have used the cone pene- meter system to determine in situ soil characteristics. nply described, the cone penetrometer system consists a cone approximately 1.5 inches in diameter attached, nt down, to a series of rods with approximately the e diameter. The cone is forced downward through the

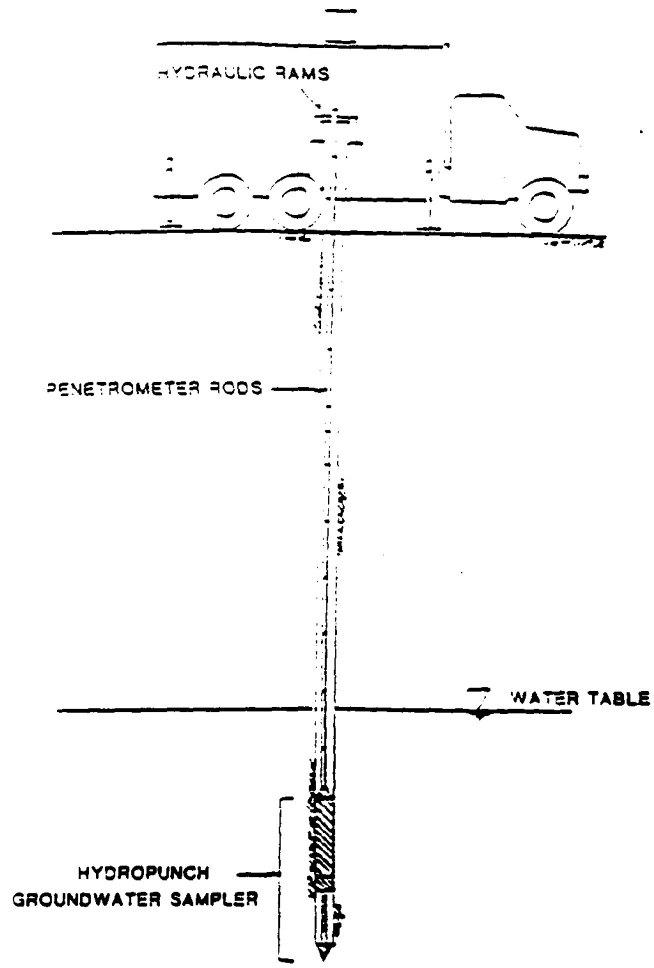


Figure 3. By replacing the standard cone with the sampling tool, the investigator can push the tool into the target area.

soil by a heavy truck or drill rig equipped with large hydraulic rams. The changes in the force required to advance the cone are recorded and correlated to changes in soil stratigraphy. The system is very fast compared to conventional drilling and soil sampling techniques and can reach depths of 140 feet in suitable geologic environments.

By replacing the standard cone with the Hydropunch ground water sampling tool, the investigator can rapidly push the tool into the target aquifer and collect ground water samples to verify contamination and to define the extent of the contaminant plume (Figure 3). The authors have collected ground water samples with a Hydropunch and cone penetrometer from 15 feet to more than 70 feet below the ground surface in approximately one hour. The cost for each sample typically ranges from one-half to one-tenth the cost of installation, development, and sampling of a conventional ground water monitoring well.

When used with a penetrometer rig, the sampling operation results in minimal impact to the surrounding environment. Drill cuttings and development water are not produced, thus eliminating the need for disposal of contaminated soil and water and minimizing cleanup and decontamination requirements. The clean, fast operation of the system is also valuable when ground water samples are needed with a minimum of disturbance to the surrounding environment.

Where geologic conditions are not suitable for use with a cone penetrometer rig, the Hydropunch can be substituted for soil sampling tools such as split barrel or California-type samplers are used with conventional drill rigs to provide chemically representative ground water samples as drilling proceeds. The sampling tool can be connected to the soil sampling rods and driven or pushed below the borehole into a zone unaffected by the drilling process. When the desired sampling depth is reached, the tool is opened, permitting a ground water sample to be collected (Figure 4). Similar to cone penetrometer sampling, the cone and sample chamber isolate the sample intake ports from fluids above and below the zone being sampled, thus formation development is not required prior to sample collection. The discrete vertical sample interval enables the Hydropunch to collect numerous samples at different depths from a single borehole.

Sampling during drilling provides a fast, economical means to investigate sites where little is known of the hydrogeology and/or where multi-aquifer systems exist. Conventional drilling and soil sampling methods can be used to define soil stratigraphy and to identify water-bearing zones. When a ground water sample is desired, a soil sampler is removed and replaced with the Hydropunch. The Hydropunch is driven into the target aquifer past the zone disturbed by the drilling process. The unit is then opened to the formation, permitting a ground water sample to be collected. Thus, a single boring can provide discrete ground water quality and piezometric data for each water-bearing zone encountered without the construction of multilevel monitoring wells. The resulting data can be used to quickly and cost-effectively determine the hydrogeologic and geochemical conditions of the study area.

Depending on the number of ground water samples collected per boring and the type of drilling equipment used, the authors have found the system to be approximately one-half to one-fourth as costly as conventional investigations using monitoring wells to collect ground water samples.

Case Histories

Northern California Municipal Landfill

The Hydropunch was used in 1985, 1986, and 1987 while conducting a ground water investigation at a landfill in northern California. The landfill was suspected of leaking low levels of volatile organic contaminants (VOCs) into the ground water. The landfill is located in a section of unconsolidated, well sorted, quartzose, brown-to-red, fine, silty sand of eolian origin containing isolated lenses of silt and clay. Underlying the sand are poorly indurated layers of sandy silt and clay interbedded with thin layers or lenses of fine-to-medium grained, silty sand. The first major aquifer encountered typically occurred 20 to 30 feet above the contact of the fine sand and the underlying silty clay. Due to the extreme topographic relief of the site, the depth to ground water ranged from 25 to more than 150 feet below the surface. The upper aquifer was the primary zone of VOC contamination at the site. Monitoring wells were installed around the perimeter of

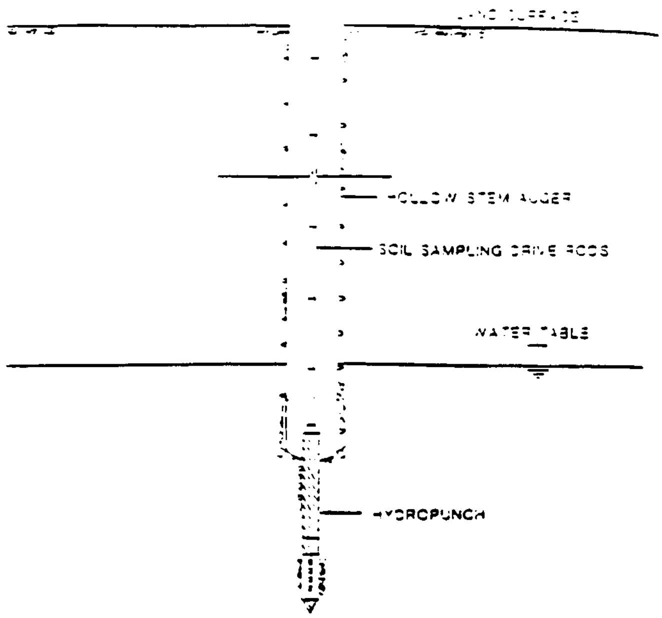


Figure 4. When the sampling depth is reached, the tool is opened.

the facility to determine if the landfill was the source of contamination and to define the extent of the contaminant plume. The Hydropunch was used in conjunction with a hollow-stem auger drilling rig to provide ground water samples as drilling proceeded.

A portable field gas chromatograph was used to provide immediate analytical results. If elevated levels of ground water contamination were found in the Hydropunch sample, a permanent monitoring well was installed in the test boring. Hydropunch samples were collected from depths ranging from 30 to 150 feet below ground surface.

By the end of the investigation it was apparent that a strong correlation could be made between contaminant concentrations found in the Hydropunch and those found in monitoring wells. The comparison may be seen in Table 1 and is discussed later. Multiple Hydropunch samples collected at various vertical intervals from the same borehole indicated that the highest contaminant

TABLE 1
Cost Comparison

Activity	Conventional Well Installation	Hydropunch with Penetrometer Rig	Hydropunch with Drill Rig
Mobilization	$ 200	$ 100	$ 100
Drilling and well installation[a]	3200	800	1200
Well development	500	—	—
Field supervision	1000	400	600
Sampling	600	425	425
Total cost	$5500	$1725	$2325
Total time	3 days	1 day	1.2 days

[a]Number of ground water samples — 5
Depth to ground water — 25 feet

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concentrations were found in the upper portion of the aquifer. Subsequent installation of monitoring wells at various vertical intervals confirmed these findings. As the investigation progressed, one very useful feature of using the Hydropunch was the capability to have geochemical results from a borehole on the same day, or at the longest within two days. This enabled the investigation to be directed based on contaminant concentrations while the drilling contractor was on-site, accelerating the progress of the investigation. As a comparison, analytical results from monitoring wells installed during the investigation were not available until approximately two months after the conclusion of the drilling program.

Southern California Schoolyard

In the spring of 1986 the Hydropunch was used with a cone penetrometer rig to confirm the presence of benzene, toluene, and xylene contamination beneath a playground at a preschool in Los Angeles, California. Ground water occurred in alluvial deposits of fine silty sand and fine sand, typically 3- to 5-feet thick, interbedded with layers of low-permeability silts and clays. The depth to ground water ranged from 6 to 10 feet below the site. The investigation required that five ground water samples be collected from a depth of about 10 to 25 feet below grade. The total field effort had to be completed over a two-day weekend to minimize the disruption of the preschool activities. By using the cone penetrometer rig to push the Hydropunch, the investigation was completed in one day, with no disruption to the school yard. The only impact to the playground produced by the sampling was five 1.25-inch-diameter holes, which were immediately backfilled with cement and bentonite and topped with an asphalt patch.

Table 1 shows a comparison between the estimated costs for a conventional well installation program at the site, an estimate of costs for a Hydropunch investigation using a hollow-stem auger drill rig, and the actual cost incurred using the Hydropunch with a cone penetrometer rig. These costs represent field costs only for collection of a single ground water sample. Total costs of the field investigation using the Hydropunch with a cone penetrometer rig were less than one-third the estimated cost associated with conventional well installation procedures. If the Hydropunch had been used with a hollow-stem auger drill rig to conduct the same investigation, it is estimated that field costs would have been less than one-half the cost of a conventional well installation.

Louisiana Petrochemical Plant

The southeastern Louisiana gulf coastal area is a region where the Hydropunch has been used effectively. Commonly, sediments encountered in this area are a reflection of a series of transgressive and regressive deltaic sequences. They are soft, unconsolidated and, in places, significantly thick. The lithologies are generally various combinations of clays, silts, and sands.

The soft sediments and shallow water table (less than 10 feet commonly) lend themselves to rapid sample acquisition. The Hydropunch has delivered as many as 12 samples in a 10-hour day. These samples were collected from as shallow as 12 feet (3.6m) and as deep as 65 feet (19.8m) below the surface.

The technique was to auger to the water table (commonly two 5-foot flights or less); remove the center plug, drive or push the Hydropunch 3 feet or more past the bottom of the auger; open the Hydropunch; allow it to fill; retrieve and collect the samples; and resume augering. Use of two Hydropunches in tandem, one to be driven into position while the other unit was being decontaminated, was very time-efficient. For vertical delineation of a plume, samples were usually collected at 5-foot increments. Fill time for the Hydropunch was found to vary with the permeability of the interval being sampled. In plastic, low-permeability clays, the fill time was 45 minutes or longer. Occasionally, clayey formation fines completely plugged the intake tube openings and no sample was obtained at all. In more permeable material, the Hydropunch filled in as little as five minutes. Generally speaking, in fine-grained sediments, the shallow samples would require a longer fill time, due to a less significant potentiometric head than deeper samples. Sample volume is contingent upon permeability of the formation and, correspondingly, the length of time the Hydropunch is allowed to fill.

During the early part of 1988, the Hydropunch was used while conducting a ground water investigation at a petrochemical facility in south Louisiana. Low levels of various chlorinated organics were suspected of being present in the ground water underlying the site. The Hydropunch was used in conjunction with a hollow-stem auger drilling rig to provide ground water samples for vertical and areal plume delineation.

The petrochemical facility provided its own laboratory services for quick gas chromatographic analysis of the ground water samples. Hydropunch samples were collected from depths ranging from 11.5 feet (3.5m) to 72 feet (21.9m) below surface. Ninety-nine ground water samples were collected from various elevations below a ground surface in 12 working days for an average of eight samples per day. Each working day consisted of approximately 10 hours. Two Hydropunches were used in tandem as described earlier. In general, with increasing sample depth, more time and effort were required. Two zones of contamination were identified. Based upon information gathered with the Hydropunch, a subsequent recovery system is in the planning stages.

Practical Considerations

Over the past three years, the Hydropunch has been used throughout the United States in a variety of hydrogeologic environments. Samples have been collected using cone penetrometer rigs and various types of drilling rigs. The design of the unit has been continuously modified to correct problems encountered during its use. A quick summation of the major problems encountered to date and the mitigative measures taken includes:

Problem—Physical deformation of sampler.

Solutions

- Do not attempt to drive sampler through extremely hard material, i.e., weathered granite, cobbles, etc. (a general rule of thumb is, if a 2-inch split-spoon sampler cannot be used, a Hydropunch sampler should not be attempted).

- Redesigned unit for greater rigidity during driving.
- Loosened internal tolerances to permit operation if minor deformation does occur.

Problem—Failure to lower check valve to close resulting in loss of sample.

Solutions

- Redesigned check valve for more positive seating.
- Reduced screen mesh size over intake tube to minimize sediment interference with check-valve operation.

Problem—Failure of intake tube to telescope into open position due to fine sand and binding moving components.

Solution

- Change locations of "O" ring seals to prevent sand from working into housing during driving.

Problem—Failure of intake tube to telescope into open position due to insufficient soil friction on drive cone.

Solution

- Reduce friction of internal moving parts to enhance sliding action.
- Lengthen and change the shape of the drive cone to increase soil friction and improve "holding" characteristics in low cohesion soils.

At present, the most common problem encountered with the use of the Hydropunch occurs when a sample is collected from a low-permeability formation. As shown in Figure 2, the interval from which the ground water sample is collected is located above the drive cone and below the body of the sampler when in the open position. This represents approximately 16 linear inches of intake area (0.4m). Consequently, fill time for the Hydropunch is directly related to the permeability of the zone exposed to the intake tube. In plastic, low-permeability clays, the time required to collect a sample has been 45 minutes or longer. In permeable soils, the Hydropunch may fill in as little as five minutes. On occasion, clay has completely plugged the intake tube openings and no sample was collected. A small-diameter electric water-level probe is lowered into the drive rods to determine when the sample chamber is full. Although slow fill times can be frustrating, some initial estimates of the zone's relative permeability can be made from the slow fill rate.

Experience has also shown that collection of samples immediately below the water table requires a longer fill time than samples collected at greater depths. This is due to a smaller potentiometric head between the sampler and the aquifer at the shallow depths.

When collecting Hydropunch samples in rapid succession (i.e., during vertical profiling or shallow ground water sampling), it is cost-effective to have two or more Hydropunches available. The use of multiple units permits decontamination of one unit while the other is in use.

Finally, as in the case with any geotechnical tool, the more experience the operator has with the Hydropunch, the better the results. It has been found that after using the Hydropunch for several days, an experienced technician can rapidly make adjustments in the field for specific hydrogeologic or drilling conditions encountered and maximize the effectiveness of the tool.

In summary, the Hydropunch has been used to detect ground water contamination and to delineate the vertical and horizontal extent of ground water contamination at sites throughout the United States. Numerous design changes have corrected mechanical problems encountered in early phases of use but factors such as low soil permeability, low hydraulic head, and operator experience [illegible] still influence the performance of the Hydropunch.

Comparison of Monitoring Well and Hydropunch Data

Table 2 shows a general comparison of water-quality data derived from Hydropunch samples and ground water samples collected from monitoring wells installed in the same borehole. The data shown in Table 2 were generated from a landfill located in northern California. The authors acknowledge that numerous variables exist between the samples. Samples were not collected from the Hydropunch and the well concurrently (there was approximately a two-month period between sampling events); consequently, chemical conditions may have changed between samples. Wells and Hydropunch samples were not collected from exactly the same intervals. Screened intervals for monitoring wells were 10 to 30 feet while the Hydropunch collects a sample from an interval of approximately 2 feet.

Detection limits and dilution ratios for sample analyses may also vary. Even with these variables, it can be seen from Table 2 that a good correlation can be made between the contaminant concentrations found in the Hydropunch samples and those found in the ground water samples from monitoring wells. Similar results have been found at other sites. In the authors' experience, the correlation provides a level of confidence that is suitable for detailed plume delineation programs.

Summary

The Hydropunch ground water sampling tool has been developed to provide ground water samples suitable for priority pollutant analysis without the installation of ground water monitoring wells. The sampler is designed to be used in two modes. A cone penetrometer rig can be used to rapidly push the unit to the desired sampling depth, or the Hydropunch can be connected to soil sampling rods permitting ground water samples to be collected during conventional drilling and soil sampling operations.

Ground water samples provided by the Hydropunch can be used to define the vertical and horizontal extent of ground water contamination and to characterize hydrogeologic conditions, enabling the investigator to eliminate unneeded monitoring wells and to correctly design and locate those wells that are required for permanent monitoring purposes.

Advantages over conventional ground water investigative techniques include:

- Ground water samples can be quickly collected (two to 10 times faster than conventional monitoring well installation and sampling).
- Ground water samples can be economically collected, typically 40 to 90 percent less costly than

TABLE 2
Comparison of Hydropunch and Monitoring Well Water Samples

Well Number	S-19		S-20		S-21*			S-23		F-2		S-12	
Source of Sample	Hydro-punch	MW	Hydro-punch	MW	Hydro-punch	Hydro-punch	MW	Hydro-punch	MW	Hydro-punch	MW	Hydro-punch	MW
Depth of Sample	35 feet	40-50 feet	121 feet	101-131 feet	119-121 feet	125-127 feet	105-135 feet	81.5-83.5 feet	55-85 feet	140 feet	134-144 feet	124.5-126 feet	122-132 feet
Volatile Priority Pollutants	Concent. μg/L	Concent. μg/L	Concent. μg/L	Concent. μg/L	Concent. μg/L	Concent. μg/L	Concent. μg/L	Concent. μg/L	Concent. μg/L	Concent. μg/L	Concent. μg/L	Concent. μg/L	Concent. μg/L
Benzene	0.3	0.1	12	20	12	5	12	0.1	ND	0.1	0.1	1.2	0.3
Chlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromochloro-methane	ND	ND	4.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	0.1	0.1	ND	ND	ND	ND	ND	0.3	0.2	ND	ND	ND	1
1-Dichloroethane	0.1	0.1	30	45	92	22	42	0.2	0.6	ND	ND	4.7	8.4
2-Dichloroethane	ND	ND	2.5	2.5	ND	ND	ND	ND	ND	ND	0.3	0.5	0.5
-Dichloroethane	ND	ND	2.5	2.5	2.5	ND	ND	ND	0.1	ND	ND	ND	0.1
1-Dichloropropane	ND	ND	2.5	2.5	ND	ND	2.5	ND	ND	ND	ND	ND	1
Ethylbenzene	0.2	ND	ND	ND	ND	ND	ND	ND	ND	0.1	0.1	0.1	ND
Methylene chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	15	10
tachloroethene	0.6	0.7	23	48	75	28	42	0.6	1.5	2.3	3	5.5	12
uene	1.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-Trichloro-ethane	ND	ND	ND	ND	ND	ND	ND	ND	0.2	ND	ND	ND	ND
2-Trichloro-nane	0.1	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
chloroethane	0.2	0.3	16	30	48	ND	25	0.1	0.3	0.2	0.2	2.8	5.3
nyl chloride	ND	ND	ND	32	ND	ND	ND	ND	ND	ND	ND	ND	ND
ns-1,2-chloroethene	ND	ND	ND	2.5	ND	ND	5	ND	ND	ND	ND	0.2	0.2
Volatile Non-Priority Pollutants													
-Xylenes	0.7	0.1	ND	2.5	ND	ND	2.5	0.1	ND	0.3	0.1	0.3	ND
ylene	0.1	ND	ND	2.5	ND	ND	ND	ND	ND	0.1	ND	ND	ND
is-1,2-Dichloroethene	2.4	2.6	48	75	158	38	65	ND	ND	0.3	0.3	4.2	2.3

o Hydropunch samples were collected.

monitoring well installation and sampling methods.

- Sample quality is suitable for priority pollutant analyses and, unlike other secondary detection techniques, provides a sample that quantifies pollutant concentrations in the ground water.
- The Hydropunch is a clean sampling system, minimizing cleanup and decontamination requirements.
- With suitable drilling techniques, the Hydropunch can provide a ground water sample from a discrete vertical interval by preventing water above and below the intake screen from entering the sampler. By collecting numerous samples from a single borehole, a vertical water-quality profile can be developed for multi-aquifer systems or stratification of contaminants can be detected within a single aquifer system.

The Hydropunch has been used with both cone penetrometer and hollow-stem auger drill rigs and has proved cost-effective in both applications. If a gas chromatograph or other analytical equipment is available on-site, sampling can be adjusted in the field to maximize the the water-quality and hydrogeologic data as they nerated. As a result, ground water investigations be completed in a fraction of the time and cost of igations using conventional well installation and ing methodologies.

Biographical Sketches

Kent Cordry is currently manager of northern California GeoStore operations and staff hydrogeologist for the Longyear Co. During the development and testing of the Hydropunch, Cordry was employed by James M. Montgomery Consulting Engineers Inc. in Walnut Creek, California, as a senior hydrogeologist. While at Montgomery, Cordry was responsible for the design and management of hydrogeologic field investigations. He has 10 years of experience in the design and installation of ground water monitoring and vadose zone sampling systems, working both as a consultant and as a contractor. He holds a B.S. degree in geology and is a certified professional geologist with the American Institute of Professional Geologists.

Russel W. Edge is currently a hydrogeologist for Roy F. Weston Inc. in Albuquerque, New Mexico. Edge has used the Hydropunch in a number of studies in various industrial settings in the Gulf Coast region and in southern California. He is responsible for designing and implementing hydrogeologic field investigations, data interpretation, report preparation, and regulatory interfacing. He holds a B.S. degree in geology from West Texas State University and has completed graduate course work at Oklahoma State University. He is a member of the National Water Well Association and the New Mexico Hazardous Waste Society.